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Remedial Action Management and Cost Analysis

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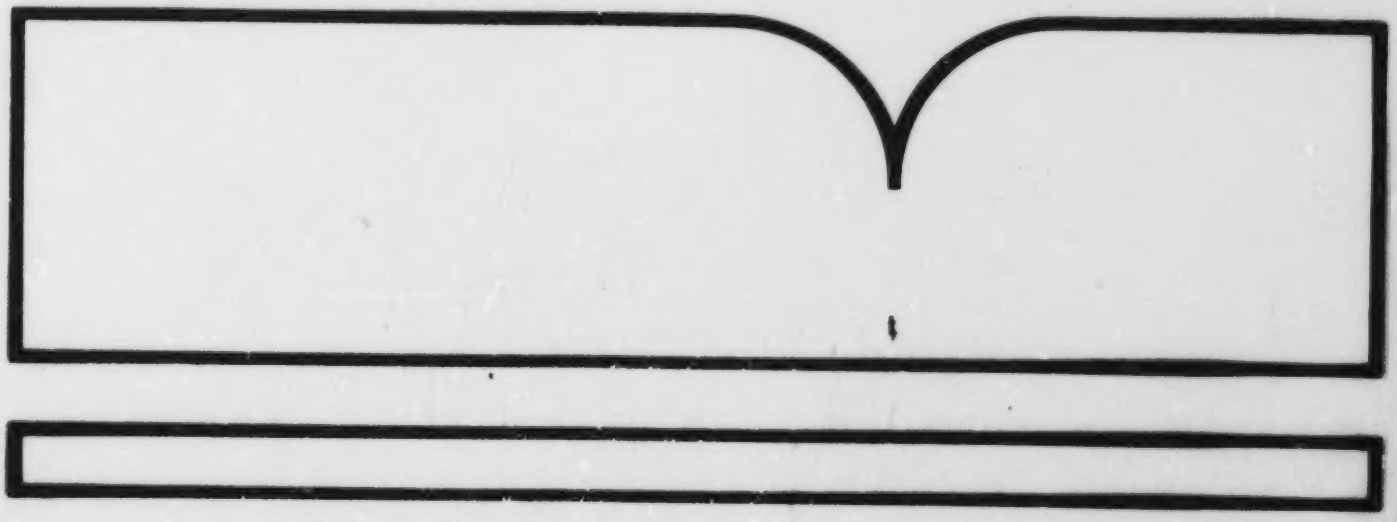

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REMEDIAL ACTION MANAGEMENT AND COST ANALYSIS

by
James D. Werner
Edward J. Yang, Ph.D.
Eric Nagle
Environmental Law Institute
Washington, D.C.

Cooperative Agreement CR 809392

Project Officer

Douglas C. Ammon
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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16. ABSTRACT The Comprehensive Environmental Response, Compensation and Liability Act of 1980, specifies statutory requirement for selection of the most "cost-effective" remedial alternative at Superfund sites. Cost effectiveness, as outlined in section 300.68, subpart F. of the National Contingency Plan, does not mean that public health concerns should be subordinated; but rather that the least cost alternative should be selected from among adequately effective options. However, carrying out this mandate for cost-effective remedies requires first, that accurate cost information be available for estimating the relative costs of remedial alternatives; and second, that this information be used to implement the remedial alternative as efficiently as possible through effective planning and management. To help provide this information to the EPA, the Environmental Law Institute (ELI) performed detailed case studies on remedial actions at 23 hazardous waste sites across the United States. These studies are a comprehensive compilation of actual expenditure data for remedial actions. This paper summarizes the findings on the costs, and the planning and management of the clean-up at these sites.

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REMEDIAL ACTION MANAGEMENT AND COST ANALYSIS *

James D. Werner
Edward J. Yang, Ph.D.
Eric Nagle

ENVIRONMENTAL LAW INSTITUTE
Washington, D.C.

INTRODUCTION

Superfund presents a classic economic and management dilemna - how to clean up the seemingly unlimited number of problem hazardous waste sites using limited resources. Congress' recognition of this dilemna is reflected in the Comprehensive Environmental Response, Compensation and Liability Act of 1980, by the specific statutory requirement for selection of the most "cost-effective" remedial alternative at Superfund sites. Cost effectiveness, as outlined in section 300.68, subpart F of the National Contingency Plan, does not mean that public health concerns should be subordinated; but rather that the least cost alternative should be selected from among adequately effective options.

However, carrying out this mandate for cost effective remedies requires first, that accurate cost information be available for estimating the relative costs of remedial alternatives; and second, that this information be used to implement the remedial alternative as efficiently as possible through effective planning and management. To help provide this information to the EPA's Superfund remedial action program, the Environmental Law Institute (ELI) performed detailed case studies on remedial actions at 23 hazardous waste sites across the United States.

* For presentation at the Fourth National Conference on the Management of Uncontrolled Hazardous Waste Sites, October 1983.

This study is the most comprehensive compilation of actual expenditure data for remedial actions that has been performed to-date. For 16 of the 23 case studies, ELI worked in conjunction with JRB Associates, which compiled the technical information at the sites. This paper summarizes the findings on the costs, and the planning and management of the clean-ups at these sites.

METHODS AND MATERIALS

Site Selection

The following information sources were used to find potential uncontrolled hazardous waste sites for case study consideration:

- 1981 SCS Engineers Survey
- EPA hazardous Material Incident Reports
- EPA Regional Offices
- State lists of hazardous substances spills responses
- Remedial contractors
- Trade Associations
- Professional contacts

From these sources, 23 sites were selected using the following criteria:

- Data availability
- Useful remedial technology
- Post-1975
- Remedial actions completed

About 385 sites were considered for study at which some remedial action, or in some cases spill response, had occurred or was planned. In practice, data availability was the most common limiting factor. For this reason, the sites may not be representative of the universe of existing uncontrolled hazardous waste sites and their remedial costs.

Roughly equal numbers of private and government financed remedial actions were chosen at 12 and 11 sites, respectively. The variety of remedial technologies included cut-off walls, subsurface drains, solidification, excavation, and ground water extraction, treatment (physical, chemical and biological) and reinjection.

Data Collection

Data were generally collected in three stages:

1. Interview preparation
2. On-site interview and file search
3. Follow-up and refinement

After obtaining permission to study a site, preliminary information was obtained to prepare for the site visit. This information helped confirm the utility of the available information, generate useful questions, and organize the component tasks and aspects of the remedial project.

Interviews and file searches during the site visit were the primary sources of cost and decision making information. All invoices, memoranda, letters, proposals, contracts, consent decrees and pleadings were photocopied. This information was typically supplemented by extensive disussions with responsible personnel, and a site tour. These sources were invaluable in providing perspective to the large volume of file material.

The last phase of the data collection process was the site visit follow-up to refine and verify the data. Again, site contacts were helpful in organizing related tasks, and specifying what activities were or were not included in a contractors invoices, as well as detailing decision making processes.

Categorization of Data

The data base resulting from this search consists primarily of three forms:

1. Invoices
2. Reports and correspondence
3. Interview notes

Cost data were constructed into functional categories by two primary means and supplemented with a variety of sources. The categorization method depended on the type of the data available from the source. The first method was the aggregation and summing of specific costs on invoices to determine the cost for a general operation such as slurry wall construction. All costs related to a particular task were totalled to derive the cost of the operation. Component costs of the total are described and dissected in the text of the particular case study. Unit costs for items like disposal or slurry mixture were multiplied with the volumes given in as-built engineering reports to double check the numbers.

The second method was the correlation of weekly invoice summaries of general cost categories with the activity occurring during that period to estimate the cost of an operation. Weekly invoice summaries were often categorized by items such as labor, equipment, transportation and disposal. These categories were broken down according to the operation to which its function contributed and the proportion of the weekly total used for that operation. For example, excavation might have been performed for 100% of a given week, and 50% of the labor and 30% of the equipment were devoted to this operation with the remainder devoted to analytical work. The cost would be further broken down if the daily reports showed that transportation and disposal occurred during two of the seven days included on the invoice for which X% labor and equipment were used for loading and analysis.

These invoice based methods were supplemented with other sources such as interviews, reports, correspondence and contracts. When aggregating specific

invoice items, particular items were sometimes explained by references to file material or the site contacts. The breakdowns of general invoice summaries according to daily reports were often refined by interviewing or corresponding by mail with site contacts about the execution and timetable for particular operations. In-house costs were estimated, when available, by totalling company time sheets for the appropriate project. In-house private party costs were the most difficult cost to obtain, usually because of the lack of available records.

Planning and management information sources varied widely. For many sites, agency correspondence provided most of the information. For private site responses the agency correspondence often included justifications for decisions. For government responses, decision making information was usually obtained through interviews. Court documents such as consent decrees provided another important source of data on planning and management. At virtually all sites, follow up phone calls were necessary for gathering supplemental decision making information. Memoranda to files were perhaps the most useful, but least common source of planning and management data.

RESULTS

Costs

The results of the research on remedial action costs of the 23 remedial actions were organized and explained in two ways. First, the cost of remedial work at each site was given, and categorized according to component tasks. A complete explanation of the costs is given in each case study, in a cost section that corresponds to the technology, and planning and management sections. Second, costs of similar remedial technologies at different sites were compared

with comparable construction - engineering manual estimates, calculated by SCS Engineers in 1980. This section of the paper will summarize the findings of these analyses.

The frequency distribution of the total costs of the remedial actions at the 23 case study sites, ranging from $23,000 to $10.3 million, is shown in Figure 1. In Table 1 the total costs of the first four of the 23 case study sites are given in alphabetical order. Also given are the problems, the response, and a quantification of the response. The year of the expenditure is given but was not found to significantly affect costs since they were all performed relatively recently. The mean total cost per site was $1.4 million. Seventeen of the 23 case study responses cost between $200,000 and $2 million.

However, the total site costs, as well as the costs for specific technologies, are not necessarily representative of the costs that should be expected in the universe of hazardous waste sites for four reasons.

First, the remedial work is not necessarily completed. Some sites were studied because of useful isolated preliminary tasks. At some sites the need and funding source for future site work remained unclear.

Second, some hidden or in-house costs were excluded. Despite attempts to include these costs, all costs were not necessarily documented. For example, private parties often did not record in-house labor, equipment and overhead costs; and government actions usually did not include administrative costs. These limitations also prevented any conclusions about the relative cost-effectiveness of private vs. public responses.

Third, costs for case study responses were incurred in a period of dynamic conditions in the remedial actions contracting market. Increased economies of scale, and increased government expertise tended to decrease costs in the more recent remedial actions, while RCRA regulations and privatization of research

Figure 1

Distribution Of Total Site Costs

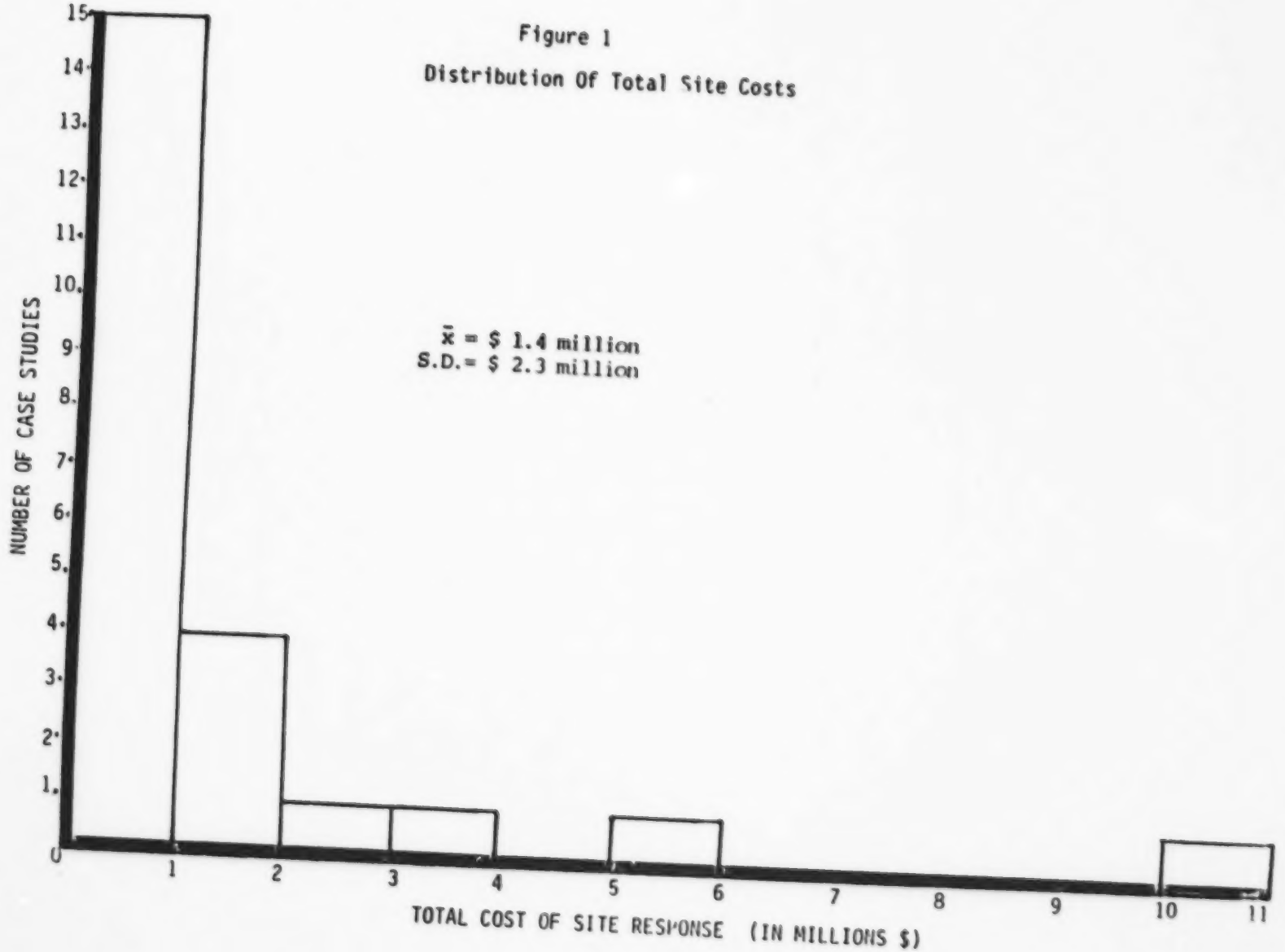

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TABLE 1. TOTAL COST BY SITE (4 of 23 sites)

Site Name	Date	Problem/Risk	Primary Response Technologies	Quantity	Total Site Cost
Anonymous Site A.	1982	pesticide/ fertilizer ponds leaked gw sw	disposal, cut-off wall	2.8×10^{10} l 9,637 m^2	$10.3 million
Anonymous Site B.	1980	solvents/ herbicide-gw	subsurface drain gw treatment	80 m long 4-5 m deep 100,000 lpd	$168,217
Anonymous Site C.	1981	hex. chromium soil, gw contamination	subsurface drain gw treatment	73 m long 4 m deep 1,000 lpd	$23,000
Anonymous Site D.	1981	solvents, gw, sw contamination	subsurface drain/ aeration, biodegradation	52,000 lpd	$926,158

gw = ground water
sw = surface water
lpd = liters per day

and development have worked to increase costs during the same period.

Finally, the site selection procedure did not attempt to assemble a group of 23 sites that were statistically representative of the range of site types and costs, which are themselves still unknown. However, the exclusionary site selection criteria that affected the lower end of the cost spectrum were probably less significant than those affecting the upper end. For example, the average total response cost may be an underestimate because the site selection procedure excluded most CERCLA-funded sites, which are generally the largest uncontrolled hazardous waste sites in the country. Also, more costly sites tend to involve litigation that rendered them unavailable for study.

The costs for four of the technologies analyzed in the case studies are summarized briefly below. These are not suggested as derived average costs for any of the technologies, but merely as the costs for four of the technologies analyzed in the case studies. Ideally the number of data points would have been allowed to approach infinity, but the availablility of data was limited because of the small of number of remedial actions that have been undertaken and that were available for study. Also, these costs inconsistently included related costs such as grading for capping, because the invoices were totalled for the entire unit of operation.

Capping - Capping cost data for 3 of the case study sites are summarized in Table 2. These four response unit costs are supplemented with significant descriptors, and compared with the SCS estimate. These costs include capital but not operation and maintenance costs. The capping costs found at the case study sites were relatively similar, ranging from \$0.95 - 1.63/ft^2 (\$10.23 - 17.55/m^2). The range of costs estimated by SCS was lower than at any case study sites. These costs are of limited comparability, however, because of the various designs of the caps; but, these variations are useful in considering significant cost factors.

TABLE 2. CAPPING COSTS

Site Name	Date	Cap Material	Thickness	Coverage	Unit Cost
Anonymous Site A.	1981	clay	6 inches (0.15 m)	(b)	$1.63/ft^2 ($17.55/m^3)
Anonymous Site B.	1981	gravel/ bentonite-soil	6 inches (0.15 m)/ 4-6 inches (0.1-0.2 m)	156,000 ft^2 (14,493 m^2)	$1.13/ ft^2 ($12.36/m^2)
	1981	asphalt	(b)	135,000 ft^2 (12,542 m^2)	1.15/ ft^2 ($12.26/m^2)
Anonymous Site C.	1980	clay	1 foot (0.3 m) (a)	100,000 ft^2 (292,681 m^2)	$0.95/ ft^2 ($10.23/m^2)
"SCS Estimate"	1980	bituminous concrete	3 inches (0.08 m)	595,953 ft^2 (55,364 m^2)	$0.61 - 0.84/ft^2 ($6.58-9.06/m2)

(a) Reported thickness in proposed design

(b) Data not available

These factors included:

A. Material Variations
   (1) Cap Material
      (a) bentonite/clay
      (b) asphalt

   (2) Related material
      (1) top gravel
      (2) gravel bed
      (3) curbs
      (4) topsoil and seeding

B. Dimensional Variations
   (1) Thickness
   (2) Area Covered

The cost data was inadequate to determine an average cost for a cap type, or to quantify the effect of a particular cost factor, but som and absence of patterns were suggested. Among material costs, the material (bentonite/clay vs. asphalt) may have been less significant the for related materials such as gravel and curbing. This is suggested by costs for the two caps at site 2. The dimensional variations such as th the area covered, may explain the lower unit costs for the SCS estimat hypothetical cap used in the estimate was much larger, resulting in economies of scale.

Cut-off walls - Cut-off wall costs for five case study sites are in Table 3. The wall size and basic composition are also given, al comparable SCS estimate. These costs include capital but not o maintenance costs. Unit costs for the case study site cut-off walls $0.21 - $29.59/ft^2 ($2.26 - $319/m^2), but, excluding the extremes, from $1.42 - $14/ft^2 ($15.13 - $150/m^2). The entire range estimated hypothetical cut-off wall was lower than the mean found at the cas The range of costs largely reflects the wide variation in the cut-off

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TABLE 3. SUMMARY OF CUT-OFF WALL COSTS (a)

Site Name	Date	Cut-off Wall Type	Size (depth underlined)	Expenditure	Unit Cost
Anonymous Site A	1980	ASPEMIX (f)	2,000 X 17 X 0.83 ft-34,000ft^2 (510 X 5 X 0.025 m - 3,159 m^2)	$238,000	$7/ ft^2 ($75/m^2)
Anonymous Site A	1982	ASPEMIX (f)	2,929 X 17 X 0.83 ft-69,734 ft^2 (893 X 5 X 0.025 m - 6,478 m^2)	$976,276	$14/ft^2 ($150/m^2)
Anonymous Site B	1980	ASPEMIX (f)	1,465 X 10 X 1 ft - 14,650 ft^2 (447 X 3 X 0.3 m - 1,341 m^2)	$83,000	$5.60/ft^2 ($61/m^2)
Anonymous Site C	1981	bentonite slurry	648 X 17 X 1ft - 11,016 ft^2 (198.6 X 5.2 X 0.3 m - 1023 m^2)	$326,000(d)	$29.59/ft^2 ($319/m^2)(d)
Anonymous Site D	1983	local clay	2,765 X 14.3 X 5ft-39,490 sq ft (843 X 4.4 X 1.5 m - 3,709 m2)	$56,118	$1.42/ft^2 ($15.13/m^2)
Anonymous Site E	1980	local clay compacted in lifts	NA (b)	NA	$0.21/ft^2 ($2.26/m^2
"SCS Estimate" (c) & (e)	1980	bentonite slurry	2,306 X 48 X 3.2 feet - 110,688 ft^2 (720 X 15 X 1 m - 10,800 m^2)	$477,300 $836,790 (e)	$4.28-7.56 /ft^2

(a) Costs are of limited comparability ; see text.

(b) Reported to be 2 feet (0.6 m) thick by design drawings

(c) Based on Means "Building Construction Cost Data: 1983.

(d) Includes excavating the trench, transporting and disposing of contaminated soil

(e) Total capital costs

(f) asphalt, sand, concrete, water emulsion

The two most significant factors affecting costs were the wall type and the disposal of the contaminated trench material. The ASPEMIX walls cost significantly more than standard clay cut-off walls, but their low permeability, demonstrated in bench scale tests, was required by the government agencies overseeing the clean-up. At site 3, the cut-off wall was constructed within the contaminated area, and hence the trench material required disposal in an engineered lanfill.

Excavation, transportation and disposal - Because of the large amount of data for excavation, transportation and disposal, only the ranges found for these costs are summarized in Table 4. The costs of RCRA hazardous waste was separated from the TSCA hazardous PCB waste because of the drastically differing costs and regulatory programs. The cost of excavating the waste (without transportation or disposal) ranged from $8-146/yd^3$ ($10-191/m^3$). Transportation costs were relatively similar at $0.13 - 0.28 ton/mile ($0.09-0.19/Mt/km.) The costs for disposal ranged from $5/Mt at an EPA subsidized landfarming operation, to $277/Mt for incineration of highly contaminated PCB oil. Most RCRA hazardous waste disposal costs were about $100/MT. No significant differences were found between disposal costs for bulk and containerized wastes.

Other factors affecting these costs were:

I. Technical

A. Excavation or On-site Transfer

1. Excavation depth
2. Site surface characteristics
3. Waste explosivity
4. Material - liquid/solid/drums
5. Waste quantity

B. Transportation

1. Distance to disposal facility
2. Accessibility to road

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3. Material - liquid vs. solid
4. Waste quantity

C. Disposal

1. PCB

a. concentration - over/under 500 ppm
b. material - solid vs. liquid

2. Non-PCB RCRA Hazardous

a. solid vs. liquid
b. aqueous vs. organic

II. Non-Technical

A. Community relations

B. Interstate relations

C Inflation and regulatory factors.

TABLE 4. RANGE OF COSTS FOR

EXCAVATION, TRANSPORTATION AND DISPOSAL

Excavation	$10/m^3$	-	$119/m^3$
Transportation	$0.08/MT/km	-	$0.18/MT/km
Disposal			
non-PCB H.W.	$10/MT (landfarming)	-	$93/MT (engineered landfill)
PCB	$212/MT (engineered landfill)	-	$277/MT (incineration)
TOTAL	$57/m^3$	-	$335/m^3$

Water treatment - Finally, costs for water treatment at eight of the 23 case study sites are summarized and compared with the comparable SCS estimate in Table 5. These costs include either: operation and maintenance costs for permanent systems constructed on-site; labor, material and rental costs for temporary on-site systems; prices charged by the contractors for water sent to commercial industrial waste treatment plants; or the prices charged by publicly owned treatment works for accepting wastewater. Capital costs were excluded from this summary because they are not consistently applicable, and because of the uncertainty about the length of the operational lifetimes for amortization purposes. Operation and maintenance costs ranged from 6-20% of capital costs.

Probably the most important factor affecting the unit costs found for treating a given volume of waste was total volume of waste treated. Systems with large capacities were able to take advantage of their greater economies of scale. For example, at site 1 only 1,000-1,500 gallons/month of water were treated; whereas at site 8, about 3.5 million gallons of water/month were treated.

Other factors found to affect these costs were:

A. Technical Factors

1. Nature and degree of contamination

   a. Treatability
   b. Solubility
   c. Concentration
   d. Diversity of contaminants

2. Variations in type of treatment processes selected

   a. Carbon
   b. Biological
   c. Physicochemical secondary treatment (POTW)
   d. Other individual treatments (e.g., air stripping, fabric filtering)

3. Variations among particular processes

   a. Level of treatment
   b. On-site/off-site
   c. Efficiency
   d. Treatment system capacity
   e. Collection limitations
   f. Climate

TABLE 5. CONTAMINATED WATER TREATMENT COST (a)

Site Name	Date	Treatment Technology	Primary Contaminant	Quantity Treated	Expenditure	Unit Cost
Anonymous Site A	1981	On-site advanced oil/water separator	PCB/oil	1,000-1,500 gallons (3,785-5678 l)/ month	$4,167/month	$2.70-4.6/gal ($0.73-1.10/l)
Anonymous Site B	1982	Off-site Commercial Treatment	Cyanide	9,425 gallons (35,674 l)	$12,724	$1.35/gallon ($0.036/l)
Anonymous Site C	1980	On-site carbon, clarification, air stripping	mixed solvents, PCB	7.8×10^6 gallons (2.9×10^9 l) over 6 month period	$2 - 3 million	$0.26-0.40/gal (b) ($0.068-0.10/l)
Anonymous Site D	1979	On-site carbon, pea gravel/lime filtration	Pentachlorophenol (PCP)	2×10^6 gallons (8×10^6 l) over 1 month period	$200,000-350,000	$0.10-0.18/gal ($0.026-0.048/l)
Anonymous Site E	1983	On-site Biodegradation	methylene chloride, butanol, acetone	13,680 gallons (51,779 l)/day	$226.53/day	$0.0165/gal ($0.0044/l)
Anonymous Site F	1982	Off-site POTW (c)	hexavalent chromium	273,000 gallons (1.03×10^6 l)	$2,275	$0.008/gallon ($0.002/l)
Anonymous Site G	1979	Off-site POTW (c)	Pesticides (atrazine, alachlor)	9×10^7 gallons (3.4×10^8 l) over 5 month period	$50,169	$0.00056/gallon ($0.00015/l)
Anonymous Site H	1982	On-site Granular Activated Carbon (reverse pulse)	Pesticides (DBCP)	$1.5\text{-}2.6 \times 10^8$ gallons ($6.8\text{-}9.8 \times 10^8$ l)/year	$133,320-370,800/year	$0.0005-0.0011/gallon ($0.00013-0.00029/l)
"SCS Estimate"	1980	On-site "Chemical, biological and/or physical"	"contaminant"	4.3×10^7 gallons (1.6×10^8 l)/year	$51,900-94,340/year	$0.0012-0.0022/gal. ($0.00032-0.00058/l)

(a) Operation and maintenance, or rental cost

(b) Includes ground water recovery cost

(c) Publicly Owned Treatment Works

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B. Non-technical Factors

1. POTW rate system
2. Use of existing system
3. Rental vs. purchase of treatment system
4. Market competition by treatment contractors
5. Inflation

Planning and Management

The five most significant factors regarding the planning and management of the remedial actions were found to be:

1) The basis for initiation of the response;

2) Public interaction with the response;

3) The basis for the extent of response;

4) The role of federal and state statutes in the execution of the response;

5) Methods for selecting and retaining contractors.

The reasons for intiating the responses were significant because 1) if they were perceived as emergencies, the choice of technologies was significanltly limited, and 2) clear identification of the nature and extent of the risk was found to provide a firm basis for designing a response strategy.

About half of the responses were intially reported to the authorities by local ciizens. Public attention was usually focused on intitiating a response, rather than on particular aspects of the response. Public interaction with the clean-up was found to be very limited. At one site, however, citizen opposition blocked five initial proposals for disposal of contaminated material. At another site, though, the local media focussed attention on the large amount of money and time being spent on what was perceived as just a minor spill.

Perhaps the most important aspect of planning and management of the case study responses, regarded the decisions about the extent of the responses. At every case study site the general goal was to eliminate the threat to public health and the environment, but specifically defining that goal took many different forms. First, the goals were chosen in in three major ways: through judicial or administrative processes, by voluntary agreement between agencies and a private party, or within the government agency undertaking the response.

The second issue studied in the planning and management of the case study responses was the specific clean-up goals chosen. The sources and types of the standards varied widely at the case study sites. Sources of the standards were important because they determined how clearly and precisely the standards were expressed, and how justifiable or defensible the standards would be if called into question. Emergency clean-ups were often terminated when the threat of fire or explosion was eliminated. These emergency actions, which were virtually all government responses, were made through a "best professional judgement" approach, rather than relying on preexisting standards. Though, in three emergency responses, the Coast Guard and/or the US EPA established specific physico-chemical clean-up goals for themselves.

Remedial actions goals were generally more thoroughly considered. However, for remedial actions at eight of the case study sites, best professional judgement was used to establish a clean-up standard. These judgements ranged from a visual notion of what constituted clean soil, to the determination of an ad hoc group of toxicologists and public health scientists who drew upon laboratory and epidemiological studies. Preexisting standards, such as landfill design criteria and NPDES discharge requirements, also served as benchmarks for clean-ups. At only two of the 23 sites was the contaminant level required to be brought to a given level. At most sites plume spread had to be halted and/or reversed, and

extracted water had to be treated to acceptable pretreatment or surface water standards. The plume control periods were all indeterminant. Specific ground water clean-up goals were determined at one site from three sources: 1) Suggested No Adverse Response Levels developed by the National Academy of Sciences; 2) Allowable Daily Intake for pesticides set by the World Health Organization; and 3) extrapolation from crop tolerances levels established by the US EPA. At other sites, states used "Action Levels" or "Levels of Concern", set by the health department, to determine clean-up requirements for soil or reinjected treatment effluent.

Generally, most of the case study responses were affected by laws governing hazardous substances or law protecting water resources, but not laws governing air quality, although air pollution was often a significant concern. The three major ways laws affected clean-ups were: 1) they provided government agencies with the authority and/or funding to initiate responses and provided funding for the work (section 311k of the Federal Water Pollution Control Act and state spill funds); 2) they provide the basis for government authorities to prompt private parties to undertake clean-ups (section 7003 of the Resource Conservation and Recovery Act, the Toxic Substances Control Act and the Federal Water Pollution Control Act); and 3) they contained design or performance standards that were used as standards for determining the extent of response (discharge requirements in the California Administrative Code for land disposal facilities, NPDES).

Two major contracting issues were studied - contractor selection methods and contract types. Generally, private parties used bidding procedures slightly more often, and allowed subcontracting much less often, than government agencies. Three major contract types were used at the case study sites: lump sum, unit price, and time and materials. Private parties used lump sum contracts,

with change orders, more often than time and materials, while government agencies had the opposite pattern. However, these generalizations should be tempered with the fact that 10 out of 11 government responses were considered to be emergency responses. Preference for unit price contracts, which involved, for example, charging a given unit price for a square foot of cut-off wall, or a cubic yard of sludge removal, was equally divided between the private and government responses.

Conclusions

The case study method was an extremely effective method for deriving useful lessons from previous remedial actions at hazardous waste sites. Important findings of the research include cost accounting procedures, contracting techniques and the importance of determining the extent of response as a management tool.

The accounting procedures used at the case study sites was found to vary widely. The research suggested that the most useful way of recording costs is to aggregate the costs according to task. In this way, it is possible to clearly determine exactly what a slurry wall cost in terms of a bottom line number useful for decision making. This method contrasts with the site-wide multiple task equipment/materials/labor breakdowns, found at many sites. This information would be most useful in a Response Summary Report, which also contains a clear summary of events and significant decisions.

The most useful contracting method seemed to be the unit price form. This contract offered the cost control advantage of lump sum contracts, but also provides the flexibility of time and materials contracts that is needed for the typically uncertain situations at hazardous waste sites. Lump sum contracts, by contrast, prompt contractors to protect themselves against these uncertainties

with explicit or hidden contingency allowances. Time and materials contracts are subject to abuse in drawn-out projects.

Finally, although the sources and use of standards varied widely at the case study sites, some type of clear end point goal seemed necessary for all sites. Planning and management of the clean-up seemed to more efficient and effective when some goal was set before committing significant resources. These goals may be altered as the work proceeded, but setting of some justifiable goal helped organize the clean-up operation, by serving as a focus for the various tasks..

Many of these findings, made elsewhere, have resulted in the planning process in Feasibility Studies, and hence serve to reinforce ongoing programs. Future revisions of the National Contingency Plan may draw upon these early lessons to improve the guidance given to future clean-ups. An objective, open appraisal of past clean-ups should continue in order to avoid reinveeting the wheel in efficiently managing remedial actions at hazardous waste sites.

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